Explanation of PQ-Box 100 Limits

The following is written to assist in the understanding of PQ-Box 100 Limits setup and EN 50160 reports. This document was written based on “WinPQ mobil” V2.13, but should also be broadly applicable to other versions.

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1. Introduction

The basis of the EN 50160 analysis report is to compare recorded data against narrow and wide limits that define your networks acceptable power quality. The methodology is that 95 % of the data should be within a set of narrow limits and 100 % of the data should be within the wide limits. The use of narrow and wide limits permits the occasional abnormal network event to occur without adversely affecting pass/fail evaluation. EN 50160 analysis considers voltage based data - it does not evaluate current or power information etc.

The EN 50160 graphical report shows a visual representation of your data – versus the limits to allow a quick pass/fail determination. The graph shows a red horizontal "95 % Limit" line, and the different evaluations are normalised and shown graphically against this limit:

- If the value is show with the red bar graph section above the Limit line, then the 95th percentile of the data has exceeded the 95 % limit
- If the value is show with the blue bar graph section above the (95 %) Limit line, but not reaching the top of the window, then the 100th percentile of the data has exceeded the 95 % limit – but has not exceeded the 100 % limit
- If the blue bar graph section is cross hatched, it will also reach the top of the window, and indicates that the highest recorded value has exceeded the 100 % limit

Simply-> a red bar graph above the line is an EN 50160 compliance fail, as is any cross hatched blue bar graph.

The Limit settings are also used within the PQ-Box 100 to generate text "Events", which are downloaded and available within WinPQ mobile as table data.

The use of the 95th and 100th percentile to evaluate data can be altered by the user. However, it is recommended to use the 95 % and 100 % values.

2. Setup of Statistic Limits (Narrow and Wide Limits)

The menu "Setup", "Common" allows the statistical limits to be set. Figure 1 shows the default and recommended values. Different values are used for different values. Different settings are also used for 3-wire and 4-wire evaluations.

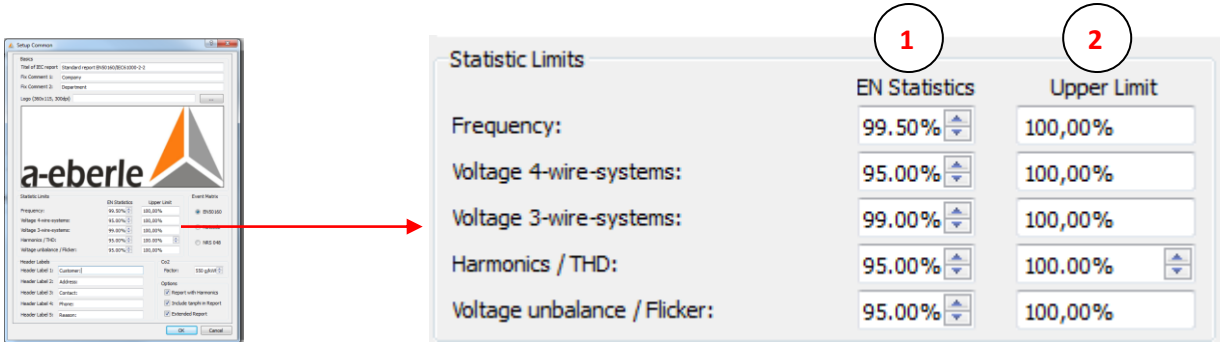


Figure 1. Default Statistic Limits.

To help identify the specific PQ-Box 100 settings referred to in this document, the red numbers in square brackets (e.g. [1]) in the text, refer to the matching callout numbers on figures and tables.

The “EN Statistics” **[1]** values are the “Narrow Limit” settings and the “Upper Limit” **[2]** is the “Wide Limit” setting. These, define the percentile values that will be used for EN 50160 limit threshold evaluation. The Narrow Limit % should be less than the Wide Limit % (e.g. Narrow = 95 %, Wide =100 %). The EN 50160 standards are based on methodology where acceptable power quality occurs when 95 % of the data is within the narrow limits and 100 % of the data is within the wide limits. The main exception is Frequency where the Narrow setting is 99.5 % and 3-wire setting is 99 %. Up/down spin controls allow some values to be altered to meet different regional needs.

When adjusting the PQ-Box 100 “Setup”, “Common” values, it will be found that the limit settings defined in Figure 1, are shown in the main Limit setup screen (Figure 2).

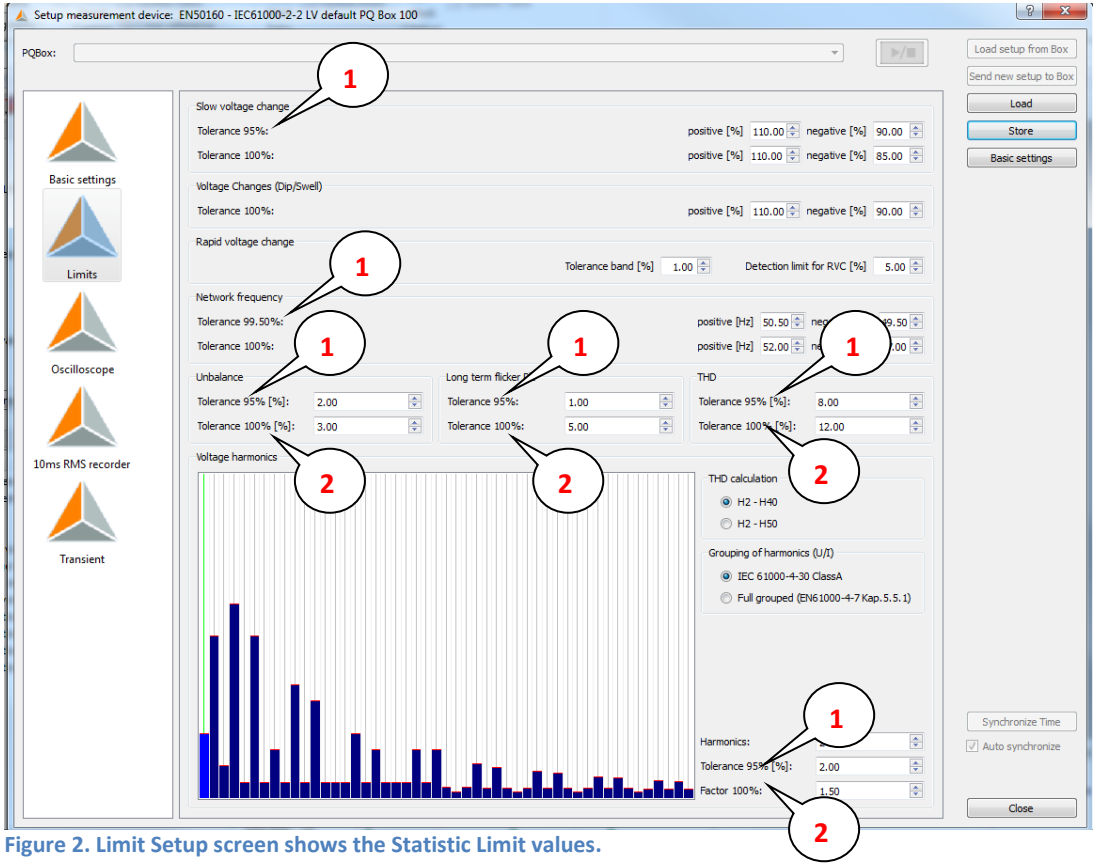


Figure 2. Limit Setup screen shows the Statistic Limit values.

Most of the parameters in the Limits Setup screen are somewhat self-explanatory. The difference between the three voltage change settings are:

- “Slow Voltage Changes” are based on the average voltage of each measuring interval (e.g. 10 minutes) – used in the EN 50160 graph
- “Voltage Changes (Dip/Swell)” are based on 10 ms r.m.s. values (this was called Fast Voltage Changes)
- “Rapid Voltage Change” is a special algorithm to detect fast voltage changes that occur within the Dip/Swell limits.

3. EN 50160 Reports

WinPQ mobil software can produce EN 50160 reports from recorded data. EN 50160 reports are based on limits defined during the PQ-Box 100 setup (Figure 1 & Figure 2). The EN 50160 reports provide a graphical overview and detailed text information.

3.1. EN 50160 Graphical Report

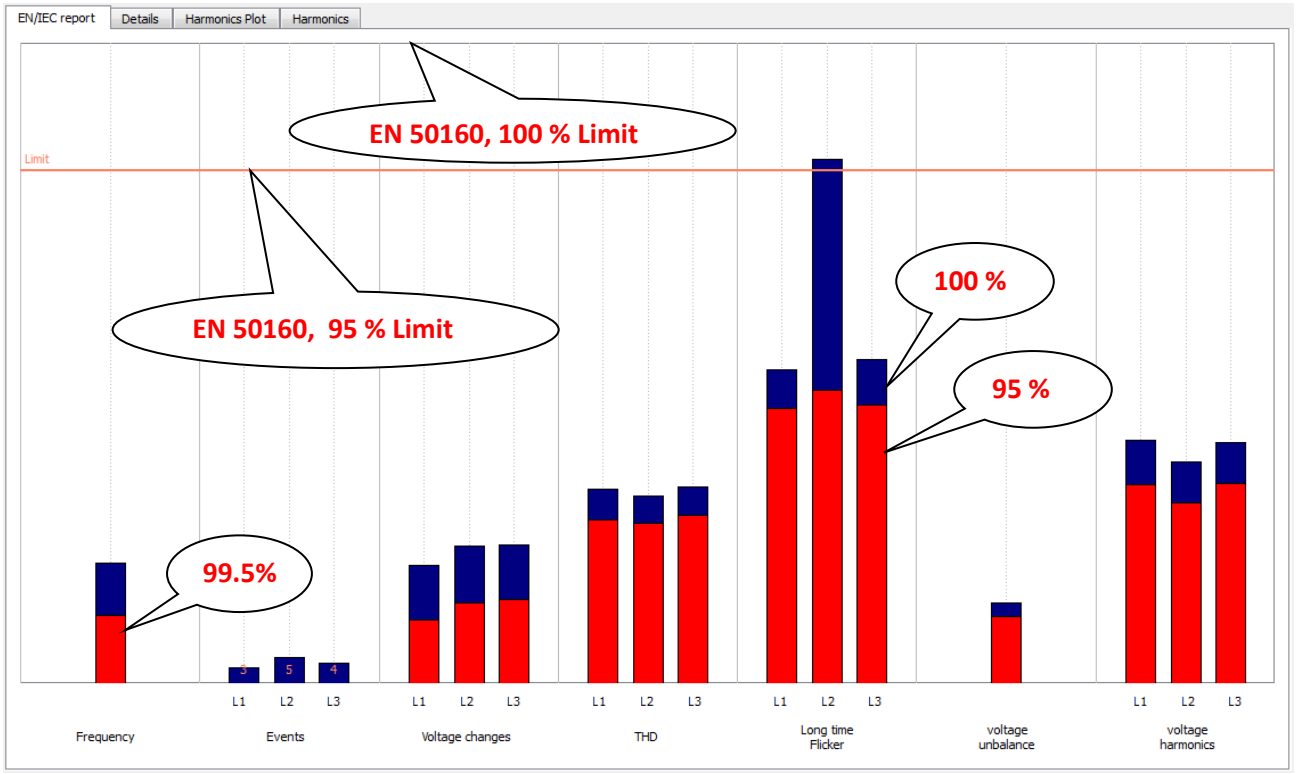


Figure 3. Example EN 50160 graphical report.

The graph shows a red horizontal "95 % Limit" line, and the different evaluations are normalised and shown graphically against this limit:

- If the value is show with the red bar graph section above the Limit line, then the 95th percentile of the data has exceeded the 95 % limit
- If the value is show with the blue bar graph section above the (95 %) Limit line, but not reaching the top of the window, then the 100th percentile of the data has exceeded the 95 % limit – but has not exceeded the 100 % limit
- If the blue bar graph section is cross hatched, it will also reach the top of the window, and indicates that the highest recorded value has exceeded the 100 % limit

The EN 50160 report graphically summarises the data conformance against the pre-set thresholds. The relative size of the red/blue portions of each vertical line can give an idea of the spread of data (i.e. stable versus unstable conditions). Figure 4 shows example where a recording has a maximum value that has exceeded the 100 % limit (but 95th percentile has not exceeded the 95 % limit).

Figure 4. Example of EN 50160 report, where 100 % limit has been exceeded – shown by cross hatch blue graph section (but the 95th percentile has not exceeed the 95 % limit).

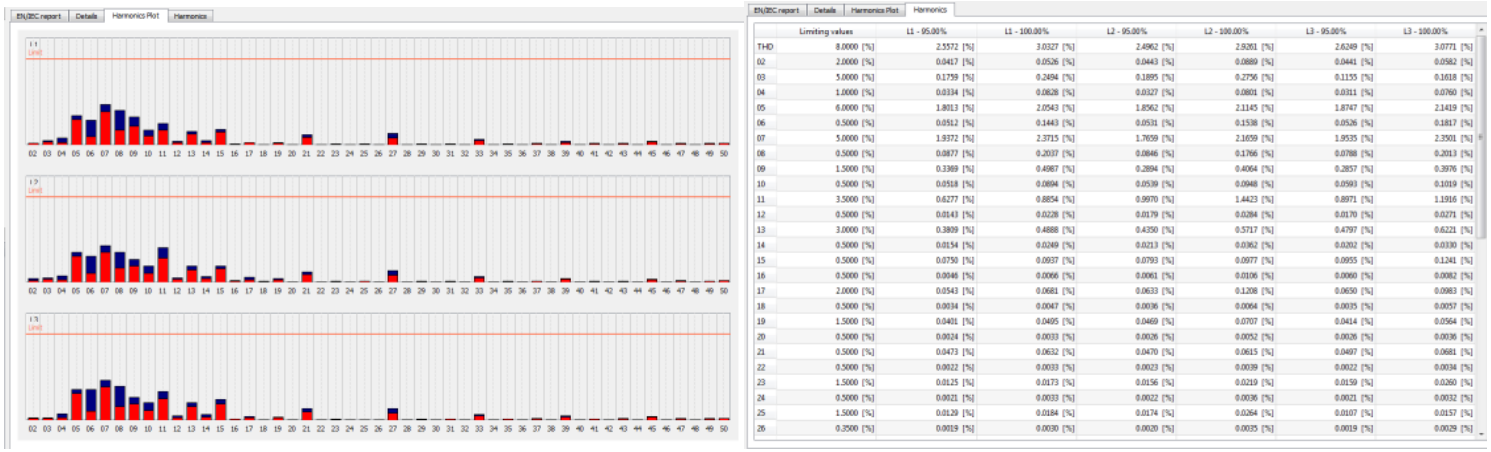


Figure 5. EN 50160 Harmonic Plot report, and Harmonic 95 % and 100 % values and limits.

The Harmonic Plot shows the individual worst case 2nd to 50th harmonic voltages (95 % and 100 % values plotted and normalised against limits). (This shows the worst case 2nd, and worst case 3rd etc – even though these may have occurred at different times during the recording). Actual 95 % and 100 % values and the compatibility levels are shown in the Harmonics tab. In the table the value is shown in red if it exceeds a limit.

3.2. EN 50160 Frequency

The EN 50160 text "Details" reports provides the following information on frequency. Note that frequency is based on a fixed 10 second evaluation period – it is not an average across the user defined measuring interval.

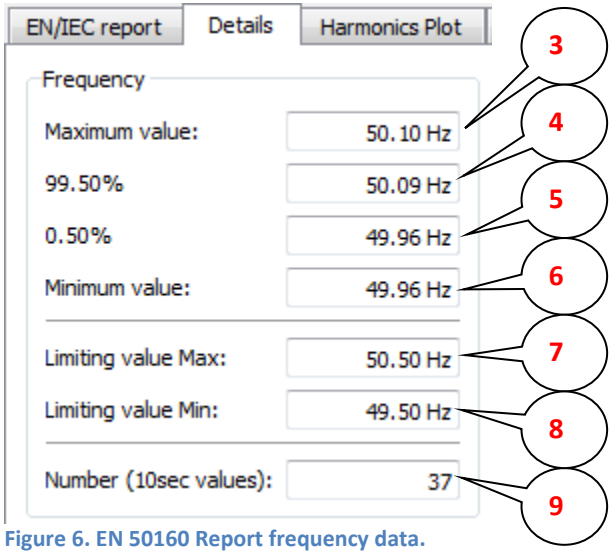


Figure 6. EN 50160 Report frequency data.

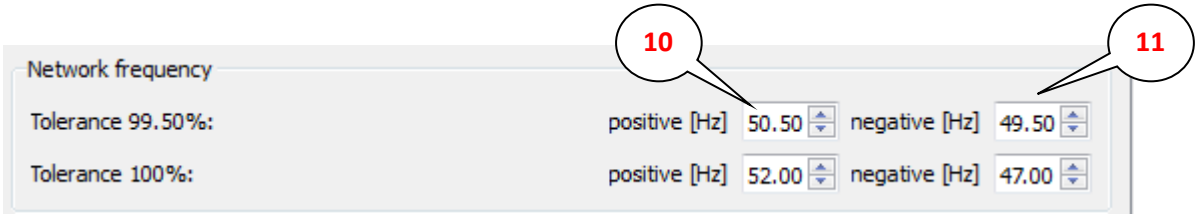


Figure 7. Example Frequency limit set ups.

[3] Maximum Value: The maximum 10 second frequency average during the recording period
[4] 99.5 %: The 99.5 % percentile (narrow limit) of the recording
[5] 0.5 %: This percentile value is "100 % less the narrow limit value", and in this case shows the 0.5 % percentile of the data
[6] Minimum value: The minimum 10 second frequency average during the recording period
[7] Limiting value Max: The Limiting value Max is set by the 99.5 % (narrow) positive threshold **[10]**. It is shown here to allow the values **[3,4,5,6]** to be compared.
[8] Limiting value Min: The Limiting value Min is set by the 99.5 % (narrow) negative threshold **[11].** It is shown here to allow the values **[3,4,5,6]** to be compared.

In the example Figure 7, the recorded data is being evaluated for compliance with frequency being within 49.5 and 50.5 Hz for at least 95 % of the total recording time, and within 47 to 52 Hz for no more than 5 % of the total recording time.

The "Number (10sec values)" **[9]** provides a count of how many 10 second measurements of frequency have been used in the statistical evaluation. The total duration of all of these 10 second intervals may be less than the total recording time, where data has been flagged. During a voltage dip, swell or interruption data is flagged and not used in the frequency evaluation. This is to stop a voltage dip/swell or interruption, also generating a frequency event. In the permanent recording graphs, display of where data is flagged can be turned on/off (right click on permanent recording graph). "Flagged" data is shown by triangles.

3.3. EN 50160 Events (graph)

This simply provides the sum of the various PQ-Events recorded for each phase. PQ-Events are described later in this document.

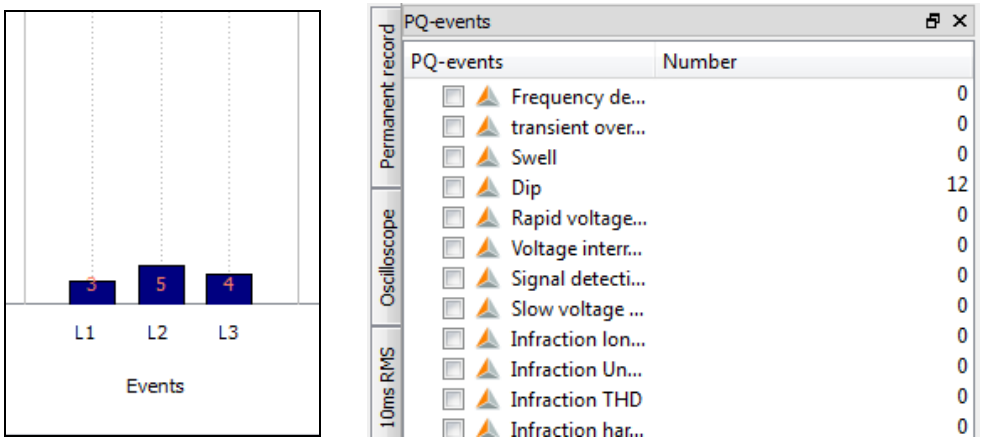


Figure 8. PQ-Events graphic summary in EN 50160 report summarises the PQ-Event table.

3.4. EN 50160 (Slow) Voltage Changes

The “Voltage Changes” in the EN 50160 graph relates to the “Slow Voltage Changes” Limit settings which are based on the average voltage of each user-defined measuring interval (i.e. the 10 minute interval if following EN 50160).

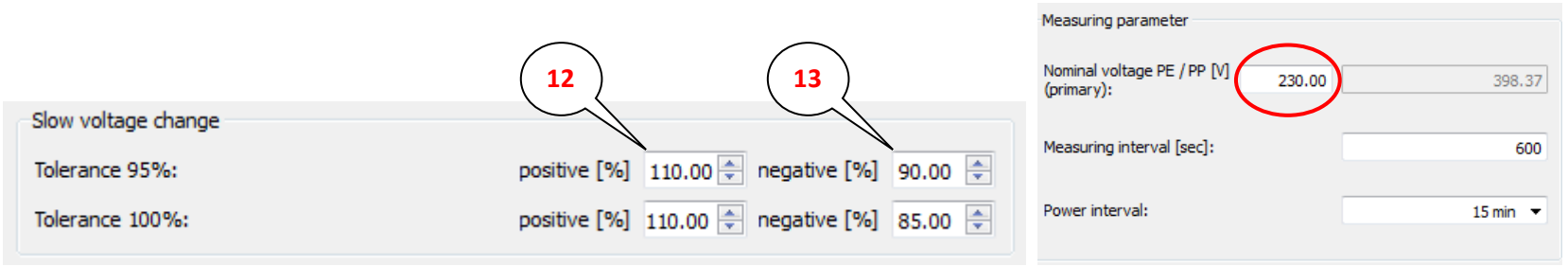


Figure 9. Slow Voltage Changes, and Nominal voltage setting.

The Slow Voltage Change settings are expressed as a percentage of the set Nominal Voltage. In Figure 9, an example of 230 V nominal is shown, thus the recorded 10 minute average voltage data will be evaluated against compliance of 95 % of the values being between 207 V (-10 % of 230 V) to 253 V (+10 % of 230 V) and 100 % of the values being between 195 V (-15 % of 230 V) and 253 V (+10 % of 230 V).

With reference to the "Voltage changes" area of the EN 50160 report text "Details" screen (Figure 10), the % values (95 % and 100 %) shown in Figure 9 were those predetermined by the PQ-Box 100 limit settings as per the setup shown in Figure 1.

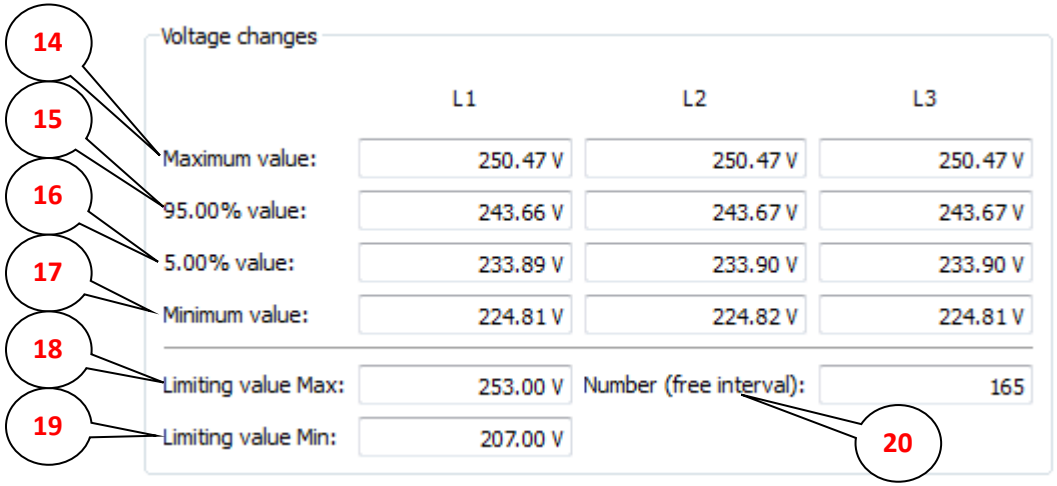


Figure 10. Example EN 50160 Details of (slow) voltage changes.

[14] Maximum Value: The maximum 10 minute average during the recording period (assuming 10 minute measuring interval is set)
[15] 95% value: The 95 % percentile (narrow limit) of the recording
[16] 5 % value: This 5 % percentile of the recording (5 % is preselected as this is "100 % - narrow limit value")
[17] Minimum value: The minimum 10 minute average during the recording period
[18] Limiting value Max: The Limiting value Max is set by the 95 % (narrow) positive threshold **[12]**. It is provide here to allow the values **[14-17]** to be compared.
[19] Limiting value Min: The Limiting value Min is set by the 95 % (narrow) negative threshold **[13]**. It is provide here to allow the values **[14-17]** to be compared.
[20] Number of Free Intervals: Number of measurement intervals used for statistics – as some data can be flagged and excluded.

Flagging:

It is important to note that EN 50160 measurements may not include data occurring during voltage dips, swells or interruptions (Flagging per IEC61000-4-30 class A, discussed in Section 5) to avoid events being double counted. ReferFigure 11 Figure 11, where it can be seen that minimum voltage value from EN 50160 report for L1 is 90.69 V **[23]**, but from permanent recording graph, it is clear the minimum voltage was approx. 58 V **[22]**. It can be seen by **[21]** that 47 intervals are recorded, but in EN 50160 report, the number of free intervals is shown as 31 **[25]**. In this example EN 50160 analysis, 16 data points have been excluded as they were classified as occurring during a voltage dip (they were below the "Limiting value Min" value **[24]**). In the permanent recording display, display of the flagged data can be turned on/off (right click on permanent recording graph). "Flagged" data is shown by triangle.

To be checked

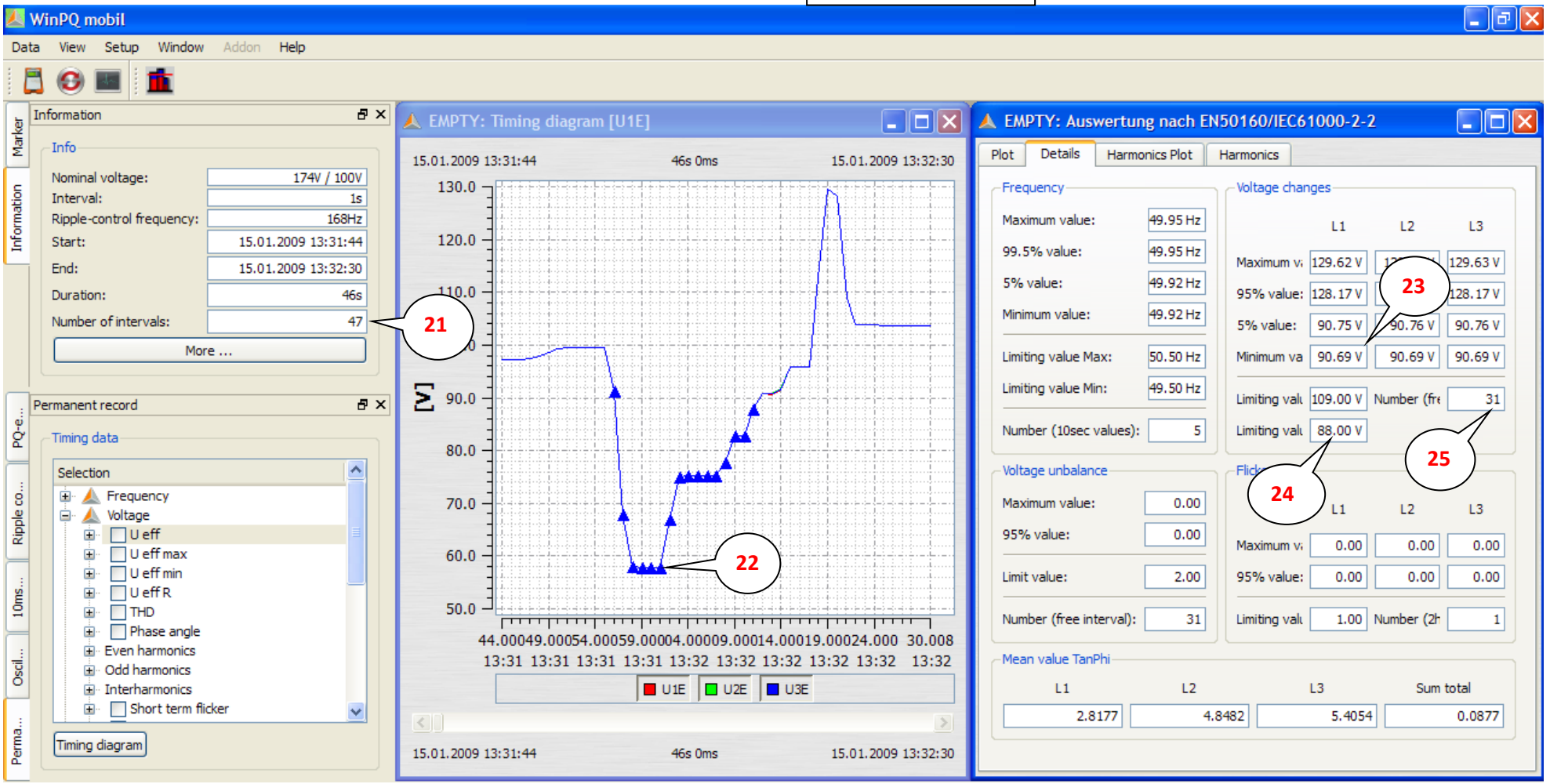


Figure 11. EN 50160 flagged data.

3.5. EN 50160 THD

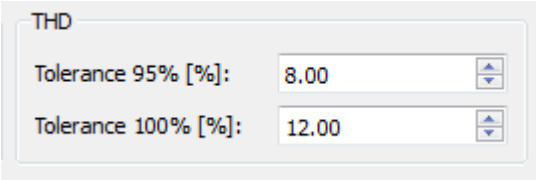


Figure 12. THD Limit Setup.

The THD narrow and wide limits are set in the PQ-Box Limits setting screen. In Figure 12, a 95 % limit of 8 % and a 100 % limit of 12 % has been set.

THD values used in the EN 50160 report are the 10 minute average values (or whatever user-defined measuring interval is being used).

Compliance to these values is shown by the normalised EN 50160 graph.

In the table report, the first data row [the one with THD in the first column] of the Harmonics table (Figure 13), provides the actual 95 and 100 percentile values for each phase. If a value exceeds the Limiting factor, the data is shown in red coloured font for easy identification of any extreme values.

EN/IEC report | Details | Harmonics Plot | Harmonics

	Limiting values	L1 - 95.00%	L1 - 100.00%	L2 - 95.00%	L2 - 100.00%	L3 - 95.00%	L3 - 100.00%
THD	8.0000 [%]	2.9830 [%]	3.0133 [%]	2.9832 [%]	3.0134 [%]	2.9827 [%]	3.0128 [%]
02	2.0000 [%]	0.0424 [%]	0.0700 [%]	0.0425 [%]	0.0699 [%]	0.0424 [%]	0.0697 [%]
03	5.0000 [%]	1.7011 [%]	1.7125 [%]	1.7010 [%]	1.7127 [%]	1.7010 [%]	1.7127 [%]

Figure 13. THD Statistics are reported in the Harmonics table.

3.6. EN 50160 Long Term Flicker

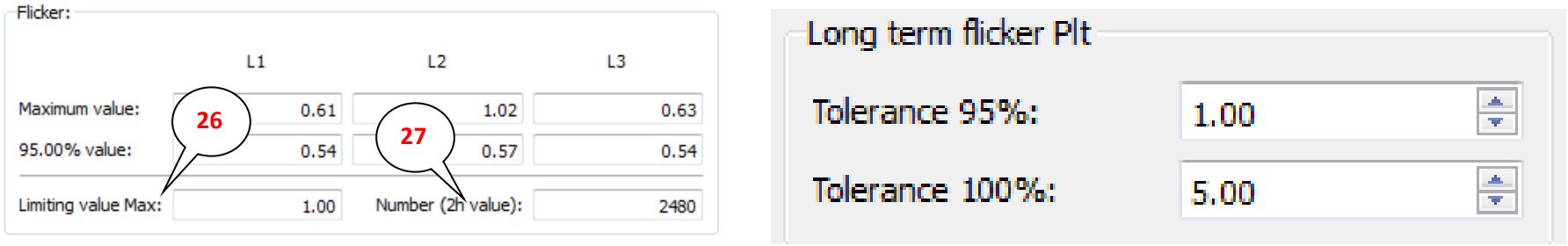


Figure 14. Statistical reporting of Long Term Flicker, and Flicker Limit Settings.

Long Term Flicker is shown on the EN 50160 normalised graph, and statistical information is provided in the "Details" tab.

Figure 14 (right) shows an example where 95 percentile and 100 percentile limits have been set (1 & 5 respectively). The left example shows the information available in the "Details" tab.

The Limiting value Max **[26]**, is the narrow limit (95 %) value. The number of 2 hour values **[25]** evaluated is also provided.

3.7. EN 50160 Voltage Unbalance

The EN 50160 Voltage Unbalance report (
Figure 15) shows the maximum and the preselected percentile unbalanced value (e.g. 95 %) during the recording period. Voltage Unbalance use the 10 minute average data values - or whatever user-defined measuring interval is being used.

Similar to others, measurements exclude flagged data. Excluded data can be identified by comparing the reported "Number (free interval)" to the total number of recorded interval for the measurement.

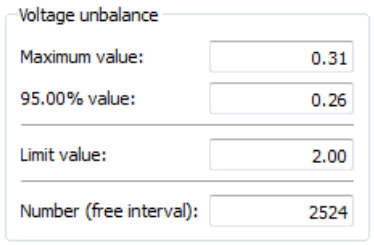


Figure 15. EN50160 Voltage Unbalance.

3.8. EN 50160 Voltage Harmonics

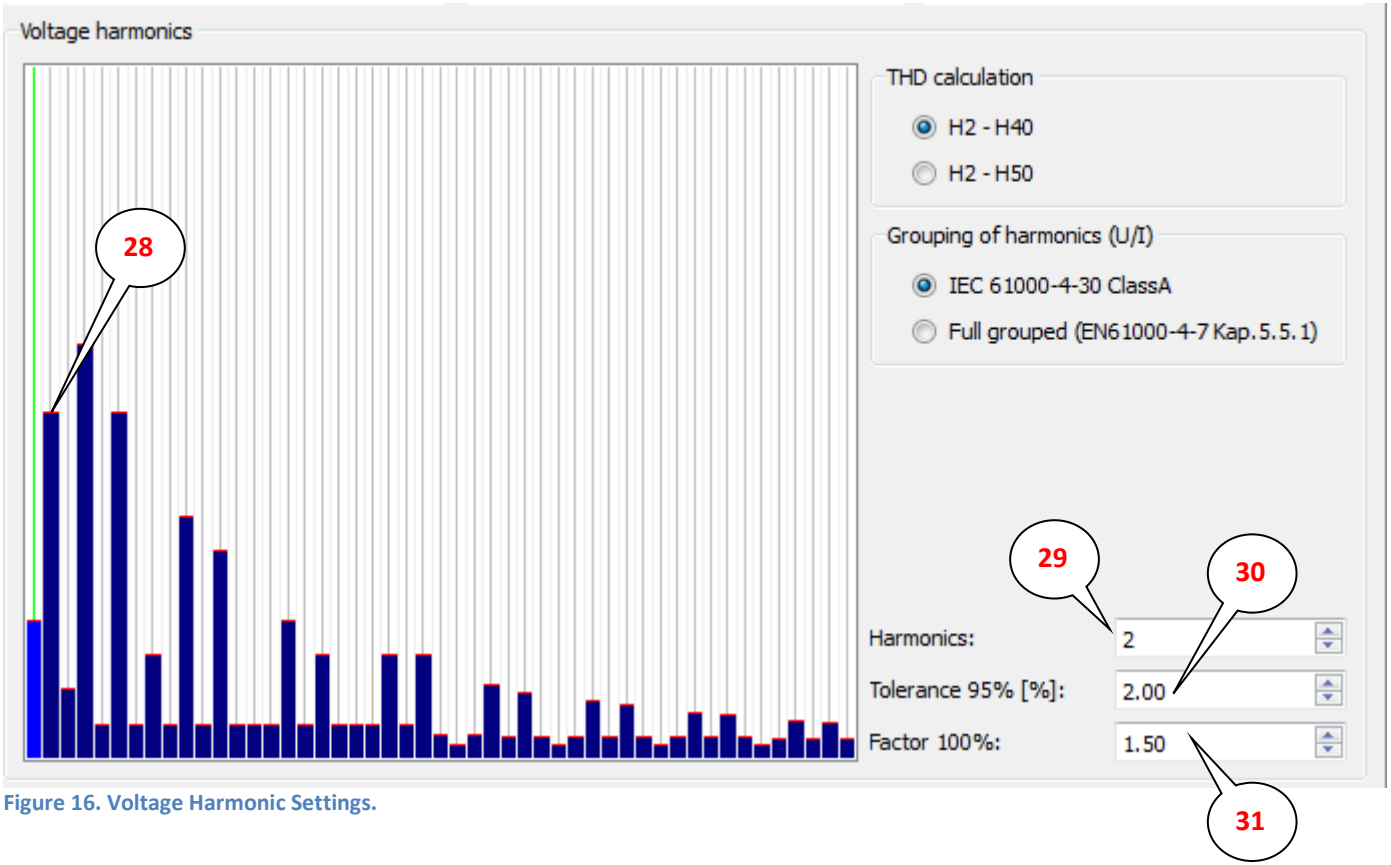


Figure 16. Voltage Harmonic Settings.

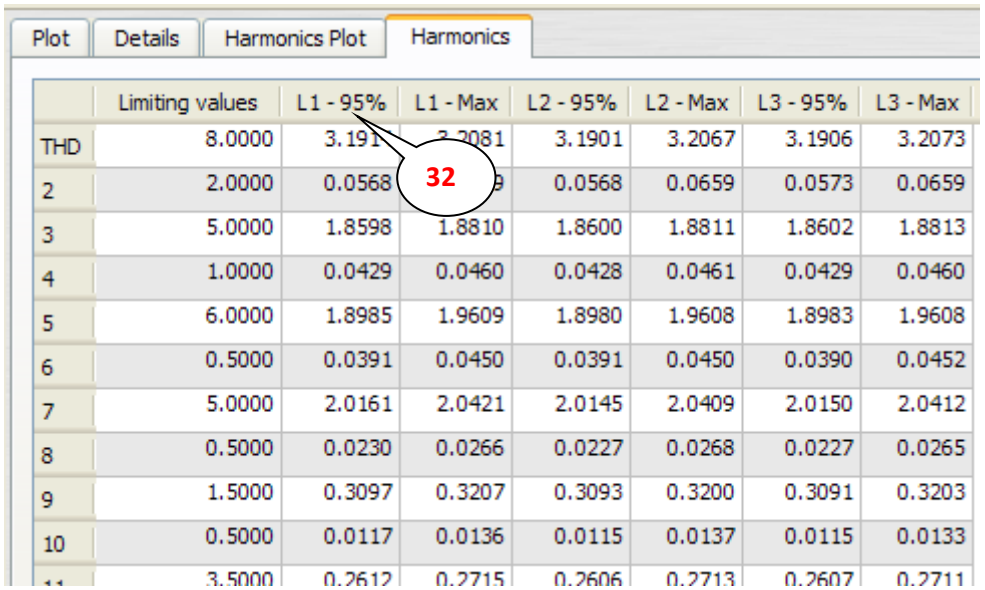
In the Voltage Harmonic limit settings (Figure 16), the narrow limit (95 %) value may be set for each individual harmonic by either dragging the top of the respective bar graph **[28]** and referring to the value displayed in **[30].** Alternatively select the desired harmonic number via **[29]** and using the up/down spin controls to set the level.

The example also shows the default EN 50160 values of 95 % and 100% percentiles being used for the evaluation, but other values can be selected using the 'Setup", "Common" controls **[1][2]**.

An individual 100% (wide) limit is not assignable to each harmonic, but rather a factor, being a multiplier **[31],** is applied to the 95 % (narrow) limit. In the example Figure 16, the 2nd harmonic setting will result in checking if harmonics are less than 2 % for 95 % of the recording time, and less than 3 % (2 % x 1.5) for 100 % of the recording.

The EN 50160 (voltage) harmonics report, provides a table listing of harmonic voltages (see example Figure 17). The first column shows the limiting values selected in the setup prior to recording (i.e. the limit setting that compliance is being checked against). The Second column **[32]** provides the percentile value based on the Narrow Limit threshold (narrow / 95 % value), the next column provides the maximum recorded harmonic level (100 % value). Further columns provide the data for the remaining phases. If a harmonic level exceeds a limiting value, it is shown in red to allow easy identification.

In this example (Figure 17) the 95 % limit for 3rd harmonic was set at 5 %. The data shows that that maximum level of L1 was 1.8810 %, and for 95 % of the time the value was less than 1.8598 %.



	Limiting values	L1 - 95%	L1 - Max	L2 - 95%	L2 - Max	L3 - 95%	L3 - Max
THD	8.0000	3.191	3.2081	3.1901	3.2067	3.1906	3.2073
2	2.0000	0.0568	0.0659	0.0568	0.0659	0.0573	0.0659
3	5.0000	1.8598	1.8810	1.8600	1.8811	1.8602	1.8813
4	1.0000	0.0429	0.0460	0.0428	0.0461	0.0429	0.0460
5	6.0000	1.8985	1.9609	1.8980	1.9608	1.8983	1.9608
6	0.5000	0.0391	0.0450	0.0391	0.0450	0.0390	0.0452
7	5.0000	2.0161	2.0421	2.0145	2.0409	2.0150	2.0412
8	0.5000	0.0230	0.0266	0.0227	0.0268	0.0227	0.0265
9	1.5000	0.3097	0.3207	0.3093	0.3200	0.3091	0.3203
10	0.5000	0.0117	0.0136	0.0115	0.0137	0.0115	0.0133
11	3.5000	0.2612	0.2715	0.2606	0.2713	0.2607	0.2711

Figure 17. Harmonic information.

Harmonic values used in the EN 50160 report are the 10 minute average values (or whatever user-defined measuring interval is being used).

4. PQ-events

The PQ-Box 100 uses the set “Limits” to also detect and record PQ-events. This occurs “live” in the PQ-Box and the LCD display Event count display is updated accordingly. The details can be downloaded by WinPQ mobil software to access the detail of the text based records (tables). These events can be listed and sorted by value/time etc. The tables can also be exported as CSV files for further evaluation.

The ITIC button provides an ITIC graph (CBEMA curve) charting PQ-Event data in the form of amplitude versus duration. An envelope showing normal power supply/equipment tolerance is provided- events plotted outside of the envelope should be investigated. The ITIC graph does not require specific PQ-Events to be selected via the check boxes - the ITIC graph automatically includes any:

- Transient voltage events
- Swell events
- Dip event
- Voltage interruption events

If using a measuring interval significantly less than the EN 50160 “10 minutes”, as the duration of the network disturbance is more likely to span one or more measuring intervals, many events (especially Slow Voltage Events) may be reported. A network disturbance may also generating more than one type of event.

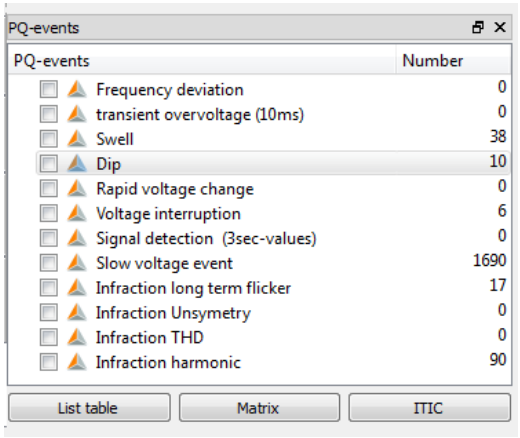


Figure 18. Possible PQ-events, with their count.

As multiple different event types can be show together in one table by selecting two or more tick boxes, all reports use common column headings. Columns such as “Harmonic” or “Duration” are left blank where data is not applicable to that event type. The “Max. Value” column should be taken to mean the ‘worst case’, as it may be a minimum value being reported (such as for voltage dips).

4.9. *Frequency deviation event*

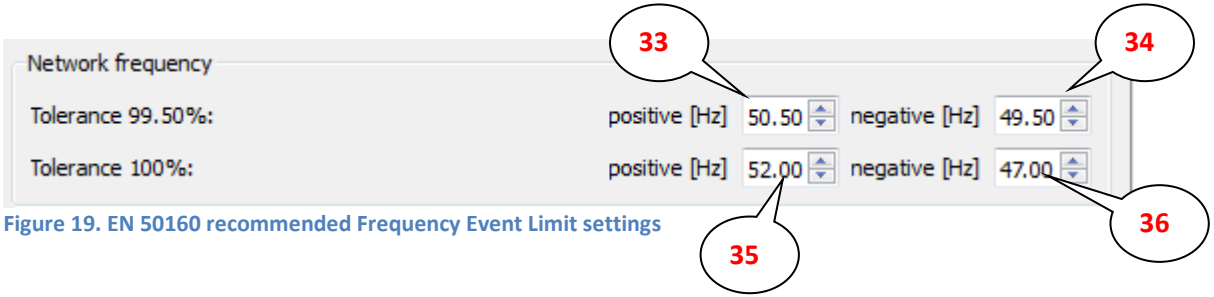


Figure 19. EN 50160 recommended Frequency Event Limit settings

A **Frequency deviation (narrow tol.)** event is generated if any 10 second frequency measurement exceeds the limits setup for narrow tolerance. That is, an event is generated if the narrow tolerance (normally 99.5 % percentile) positive **[33]** or negative **[34]** limit is exceeded. The event data reports maximum excursion, start/stop time and duration. Figure 20 provides an example.

A **Frequency deviation (wide tol.)** event is generated if any 10 second data exceeds the limits setup for wide tolerance. That is, an event is generated if the wide tolerance (normally 100 % percentile) positive **[35]** or negative **[36]** limit is exceeded. The event data reports maximum excursion, start/stop time and duration.

	Event	Start Time	Max. Value	Harmonic	End Time	Duration
1	Frequency deviation (narrow tol.)	12.11.2014 14:28:40	50.0407	---	12.11.2014 14:29:30	49s 991ms
2	Frequency deviation (narrow tol.)	12.11.2014 14:29:40	50.0295	---	12.11.2014 14:30:20	39s 992ms
3	Frequency deviation (wide tol.)	12.11.2014 14:29:40	49.977	---	12.11.2014 14:30:00	20s 9ms
4	Frequency deviation (narrow tol.)	12.11.2014 14:30:40	50.0618	---	12.11.2014 14:30:59	19s 989ms

Figure 20. Example frequency events (Has used more sensitive trigger settings than above to generate these events).

In the example Figure 20, the wide tolerance event (#3) is actually the due to the negative tolerance (minimum) being exceeded – which can be identified from the setting data. As multiple different event types can be show together in one table by selecting two or more tick boxes, all reports use common column headings. The "Max. Value" column should be taken to mean the 'worst case', as in this case it is a minimum value being reported.

As the Frequency event uses 10 sec values, it is therefore independent of the measuring interval.

- If multiple events occur within a measuring interval, multiple events are captured (not just the worst case maximum value for the interval):
- If an event spans one or more measuring interval, it is still classed as a single event

When evaluating the reported time of frequency events two facts need to be considered:

1. Frequency is measured based on measurement over a 10 second duration (IEC 61000-4-30), thus the resolution of time reported for any frequency event will be in 10 second increments
2. Time stamping of events, occurs within 10ms of the real time clock

4.10. Transient Overvoltage (10ms) event

This event occurs when the 10 ms voltage exceeds a define threshold of Nominal Voltage. The threshold percentage is 200 % of nominal, and cannot be altered by the user.

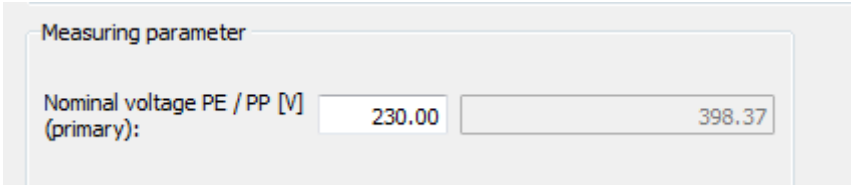


Figure 21. Transient Overvoltage (10ms) trigger threshold is fixed at 200 % of the Nominal Voltage setting.

As the Transient Overvoltage (10ms) event uses 10 ms values, it is therefore independent of the measuring interval.

- If multiple events occur within a measuring interval, multiple events are captured (not just the worst case maximum value for the interval)
- If an event spans one of more measuring interval, it is still classed as a single event

	Event	Start Time	Max. Value	Harmonic	End Time	Duration
1	Overvoltage UL1	14.11.2014 09:47:39	476.436	---	14.11.2014 09:47:39	0s 280ms
2	Overvoltage UL2	14.11.2014 09:47:39	476.444	---	14.11.2014 09:47:39	0s 280ms
3	Overvoltage UL3	14.11.2014 09:47:39	476.439	---	14.11.2014 09:47:39	0s 280ms

Figure 22. Transient Overvoltage (10ms) event example.

4.11. Swell event

A Swell event is generated if a 10 ms voltage goes above the "Voltage Changes (Dip/Swell)" positive % limit **[37].** (The Dip event is similar, but where the voltage goes below the negative limit **[38].**)

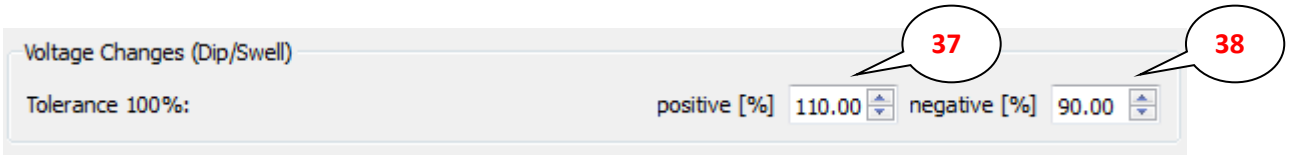


Figure 23. Default settings for Swell events.

As the Swell event uses 10 ms values, it is therefore independent of the measuring interval.

- If multiple events occur within a measuring interval, multiple events are captured (not just the worst case maximum value for the interval):
- If an event spans one of more measuring interval, it is still classed as a single event

	Event	Start Time	Max. Value	Harmonic	End Time	Duration
1	Swell UL1	11.11.2014 14:03:12	361.973	---	11.11.2014 14:03:13	0s 641ms
2	Swell UL2	11.11.2014 14:03:12	362.013	---	11.11.2014 14:03:13	0s 641ms
3	Swell UL3	11.11.2014 14:03:12	362.003	---	11.11.2014 14:03:13	0s 641ms
4	Swell UL1	11.11.2014 14:03:14	366.146	---	11.11.2014 14:03:14	0s 670ms
5	Swell UL2	11.11.2014 14:03:14	366.181	---	11.11.2014 14:03:14	0s 670ms
6	Swell UL3	11.11.2014 14:03:14	366.173	---	11.11.2014 14:03:14	0s 670ms
7	Swell UL1	11.11.2014 14:03:59	342.72	---	11.11.2014 14:04:52	53s 725ms
8	Swell UL2	11.11.2014 14:03:59	342.76	---	11.11.2014 14:04:52	53s 725ms
9	Swell UL3	11.11.2014 14:03:59	342.748	---	11.11.2014 14:04:52	53s 725ms

Figure 24. Example Swell events.

Note that the final events on the list may not report a duration, if the PQ-Box 100 recording is stopped before the voltage returns to within "normal" thresholds.

4.12. Dip event

A Dip event is generated if a 10 ms voltage goes below the “Voltage Changes (Dip/Swell)” negative % limit **[38].** It is the opposite of a Swell event.

Refer to Swell event (Section 4.11) for more details.

As multiple different event types can be show together in one table by selecting two or more tick boxes, all reports use common column headings. The “Max. Value” column should be taken to mean the ‘worst case’, as it is a minimum value being reported.

4.13. Rapid Voltage Change event

Rapid Voltage Change (RVC) are measured in accordance with IEC 61000-4-30.

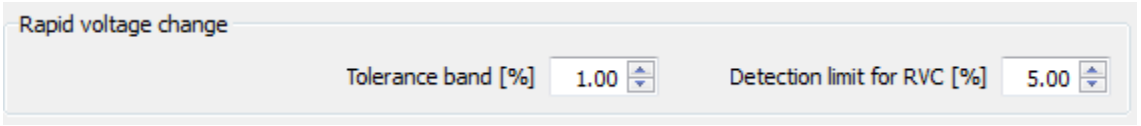


Figure 25. Default settings for Rapid Voltage Change Event.

A Rapid Voltage Change is a voltage change that occurs between two steady states. The ‘Tolerance band’ defines the acceptable voltage range permissible to be considered ‘steady state’. The voltage must be within this range for at least 1 second. The ‘Detection limit for RVC’ sets the trigger threshold limit that must be exceeded between two sequential steady state conditions for the event to be classified as a RCV event.

The typical settings for rapid voltage change are:

- Tolerance Band = 1 %
- Detection Limit for RVC (%) = 5 % (Normally in range of 5-10 %, but less than Dip/Swell limits)
- Note that any voltage excursion passed the Dip/Swell threshold limits will not be a RVC, but rather a Dip/Swell event.

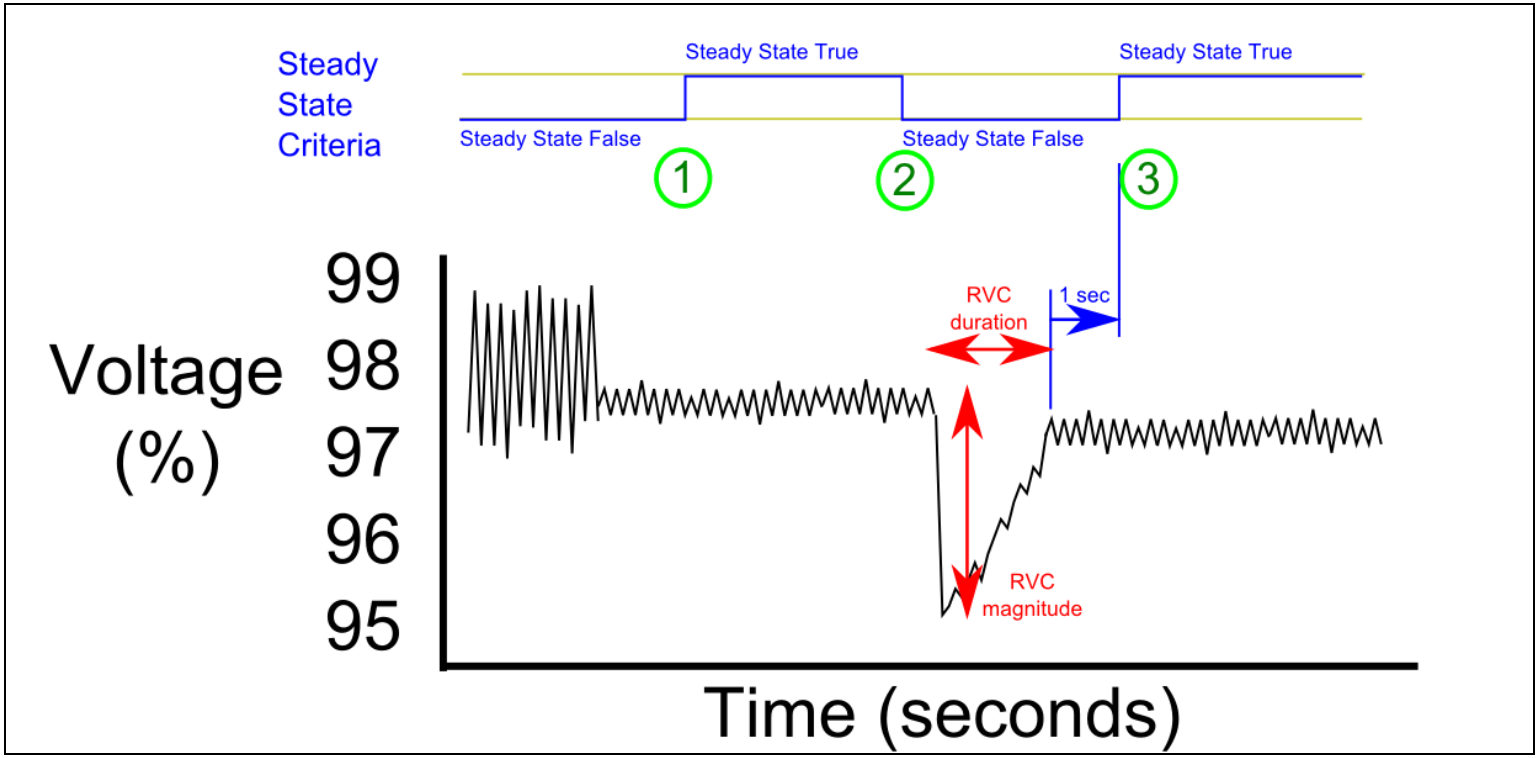


Figure 26. 'Rapid Voltage Change' defined.

Figure 26 is provided to give an illustration of a RVC event. The first steady state true condition (1) occurs after nominal voltage variations have been within the 1 % tolerance for 1 second. This steady state ends (2) when voltage variation exceeds the 1 % setting. A second steady state condition occurs at (3) as voltage variations returned to within 1 % tolerance for at least 1 second. As the maximum magnitude of the change occurring between the two steady states was a) greater than the 5 % detection limit and b) less than the dip/swell setting, this event is classified as a RVC, with its duration and magnitude being recorded.

As RVC's are not an EN 50160 evaluation criteria, the RVC data is only available via the PQ-events tab. In Figure 27, an example RVC event (#1) shows a negative 15.5334 voltage change has occurred, with 200 ms duration.

	Event	Start Time	Max. Value	Harmonic	End Time	Duration
1	Rapid voltage change UL1	17.08.2014 15:14:05	-15.5334	---	17.08.2014 15:14:05	0s 200ms
2	Rapid voltage change UL1	17.08.2014 19:40:54	-11.5433	---	17.08.2014 19:40:54	0s 80ms

Figure 27. Example 'Rapid Voltage Change' event report.

4.14. Voltage Interruption

A Voltage Interruption event is generated if 10 ms values should fall below 99 % of 'nominal' voltage (the main "Nominal Voltage" Measuring Parameter").

As the Voltage Interruption event uses 10 ms values, it is therefore independent of the measuring interval.

- If multiple events occur within a measuring interval, multiple events are captured (not just the worst case maximum value during that interval):
- If an event spans one of more measuring interval, it is still classed as a single event

	Event	Start Time	Max. Value	Harmonic	End Time	Duration
1	Voltage interruption UL1	11.11.2014 14:26:35	0.617248	---	11.11.2014 14:26:45	9s 678ms
2	Voltage interruption UL2	11.11.2014 14:26:37	1.03673	---	11.11.2014 14:26:43	6s 39ms
3	Voltage interruption UL3	11.11.2014 14:26:39	0.617555	---	11.11.2014 14:26:42	2s 550ms

Figure 28. Example Voltage Interruption Report.

As multiple different event types can be show together in one table, all reports use common column headings. The "Max. Value" column should be considered to be reporting the 'worst case', as for Voltage Interruptions it is a minimum value being reported.

4.15. Signal detection (3 sec-value) event

This event will be generated if the PQ-Box 100 detects a frequency signal greater than the EN 50160 limit. This is based on a 3 second average measurement with trigger level as shown in Figure 29, defined by EN 50160.

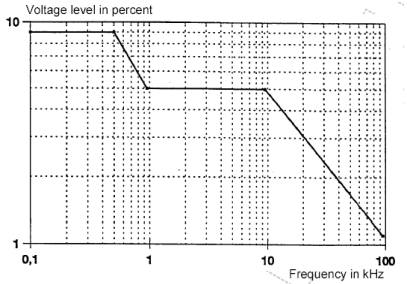


Figure 29. Mains signalling voltage trigger threshold.

4.16. Slow Voltage event

This is closely related to the EN 50160 “Voltage Changes” parameter, where the 10 minute (or whatever user-defined measuring interval is being used) average is compared to the narrow (95 %) limit settings **[39] & [40]**.

An event is generated at the end of each measuring interval if:

- The average measuring voltage exceeds the Slow Voltage Change narrow tolerance (95 %) positive threshold **[39]**
- The average measuring voltage is lower than the Slow Voltage Change narrow tolerance (95 %) negative threshold **[40]**

Figure 30. Slow Voltage Change settings are used both for PQ-Events and EN 50160 Analysis. Default values shown.

	Event	Start Time	Max. Value	Harmonic	End Time	Duration
1	Slow voltage change UL1	11.11.2014 14:59:30	258.916	---	11.11.2014 14:59:30	---
2	Slow voltage change UL2	11.11.2014 14:59:30	258.944	---	11.11.2014 14:59:30	---
3	Slow voltage change UL3	11.11.2014 14:59:30	258.937	---	11.11.2014 14:59:30	---
4	Slow voltage change UL1	11.11.2014 14:59:40	259.004	---	11.11.2014 14:59:40	---
5	Slow voltage change UL2	11.11.2014 14:59:40	259.032	---	11.11.2014 14:59:40	---
6	Slow voltage change UL3	11.11.2014 14:59:40	259.024	---	11.11.2014 14:59:40	---
7	Slow voltage change UL1	11.11.2014 14:59:50	258.925	---	11.11.2014 14:59:50	---
8	Slow voltage change UL2	11.11.2014 14:59:50	258.952	---	11.11.2014 14:59:50	---
9	Slow voltage change UL3	11.11.2014 14:59:50	258.945	---	11.11.2014 14:59:50	---
10	Slow voltage change UL1	11.11.2014 15:00:10	195.899	---	11.11.2014 15:00:10	---
11	Slow voltage change UL2	11.11.2014 15:00:10	195.92	---	11.11.2014 15:00:10	---

Figure 31. Example Slow Voltage Change Report.

As this data is evaluate for each measuring interval, if the voltage is low (or high) for successive intervals, separate events are generated for each interval. In Figure 31 for example, a 10 second measuring interval was being used and it can be determined from the time stamp that Event #1,#4 & #7 are successive events. The report does not provide data in the duration column as by definition, any Slow Voltage Change event duration will be equal to the set measuring interval. (The “Start Time” and “End Time” columns do report the same information – being the end of the measuring interval).

Figure 31, also shows how low voltages are reported. Event #10 for example reports the “Max. Value” as being 195.899 V. This event was where the average voltage for the measuring interval was less than the negative limit **[40]**.

4.17. Infraction long term flicker

This event will be generated if the Plt long term exceeds the 95 % limit threshold **[41]** defined in the setup.

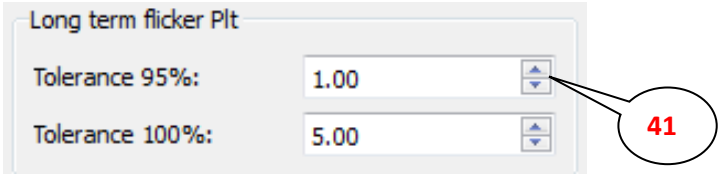


Figure 32. Infraction Flicker long term, limit is set by the narrow setting.

	Event	Start Time	Max. Value	Harmonic	End Time	Duration
1	Infraction flicker long term UL1	21.07.2010 20:00:00	81.4898	---	21.07.2010 20:00:00	---
2	Infraction flicker long term UL2	21.07.2010 20:00:00	81.07	---	21.07.2010 20:00:00	---
3	Infraction flicker long term UL3	21.07.2010 20:00:00	81.2046	---	21.07.2010 20:00:00	---
4	Infraction flicker long term UL1	22.07.2010 10:00:00	1.43745	---	22.07.2010 10:00:00	---
5	Infraction flicker long term UL2	22.07.2010 10:00:00	1.28745	---	22.07.2010 10:00:00	---

Figure 33. Example flicker report.

As this measurement is based on 2 hour average, a separate event will be generated for each measuring interval where the limit is exceeded. Therefore duration is not reported. (The “Start Time” and “End Time” columns report the same time – being the end of the measuring interval).

4.18. Infraction Unsymetry (Asymmetry- UU Unbalance)

This event will be generated if the 10 minute interval average (or whatever measuring interval has been set) voltage imbalance exceeds the 95 % limit threshold **[42]** defined in the setup.

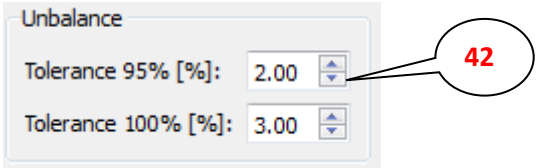


Figure 34. UU Unbalance Event setting is based on 95% limit.

	Event	Start Time	Max. Value	Harmonic	End Time	Duration
1	UU Unbalance	16.01.2009 10:47:50	99.851	---	16.01.2009 10:47:50	---

Figure 35. Example Event report.

As this measurement is based on average during the measuring interval, a separate event will be generated for each measuring interval where the limit is exceeded. Therefore duration is not reported. (The “Start Time” and “End Time” columns report the same time – being the end of the measuring interval)

4.19. Infraction THD

This event will be generated if the average voltage THD exceeds the 95 % limit threshold **[43]** during the measuring interval.

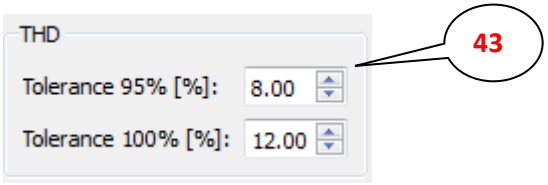


Figure 36. THD Event threshold setting (95 % limit).

	Event	Start Time	Max. Value	Harmonic	End Time	Duration
1	Infraction THD U1E	16.01.2009 08:44:16	3.00472	---	16.01.2009 08:44:16	---

Figure 37 .Example THD Event.

As this measurement is based on average during the measuring interval, a separate event will be generated for each measuring interval where the limit is exceeded. (The “Start Time” and “End Time” columns report the same time – being the end of the measuring interval).

4.20. Infraction harmonic

This event will be generated if the average of any one harmonic voltage exceeds the 95 % limit for that harmonic, during each measuring interval. It is likely that for a single measuring interval multiple events will occur as each harmonic is considered separately. The limits for each harmonic are set per example **[30]**.

	Event	Start Time	Max. Value	Harmonic	End Time	Duration
1	Infraction harmonic U2E	16.01.2009 08:48:58	---	2	16.01.2009 08:48:58	---

Figure 38. Individual harmonic event reporting.

As this measurement is based on average during the measuring interval, a separate event will be generated for each measuring interval where the limit is exceeded. (The "Start Time" and "End Time" columns report the same information – the end of the measuring interval). This is the only PQ-Event report to make use of the "Harmonic" column.

4.21. Overview of different Voltage Events

The following summarise/compares some of the different PQ-Event methods.

Events based on 10 ms values	**Events based on measuring interval**
• Transient overvoltage (10 ms) • Swell • Dip • Voltage interruption	• Slow voltage events (max. and mins.) • Infraction Unsymetry • Infraction THD • Infraction harmonic
Other time bases: • Frequency deviation = 10 second values • Rapid Voltage change • Signal detection (3 sec values) • Infraction long term flicker (2 hours)	

Table 1. Time bases of different PQ-Events.

Be aware that it is possible for one network event depending upon its characteristic to generate multiple events such as a supply interruption, a dip and a slow voltage change. However, the ITIC (CBEMA) report, will only report the worst case event.

PQ-Event	Trigger condition
Transient Overvoltage (10ms)	A Transient Overvoltage event is generated if a 10 ms value exceeds a factory set threshold above the nominal voltage value The start and stop time with duration and max amplitude is reported. If the duration spans multiple measuring intervals, only one event is generated.
Swell	A Swell event is generated if the voltage exceeds the "Voltage Change (Dip/Swell)" positive threshold. (Normally +10 %). The start and stop time with duration and max amplitude of the Swell is reported. If the duration spans multiple measuring intervals, only one event is generated.
Dip	A Dip event is generated if the voltage falls below the "Voltage Change (Dip/Swell)" negative threshold. (Normally -10 %). The start and stop time with duration and max amplitude of the Dip is reported. If the duration spans multiple measuring intervals, only one event is generated.
Voltage interruption	A voltage interruption event is generated if 10 ms r.m.s values should fall below 99 % of the main Nominal Voltage setting. The start and stop time with duration and minimum amplitude of the Interruption is reported. If the duration spans multiple measuring intervals, only one event is generated.
Slow Voltage event	A slow voltage change event is generated if the average voltage during a measuring interval is: • less than the 95 % negative limit threshold • more than the 95 % positive limit threshold The "Max. Value" reported is the average voltage during the measuring period. Start time reported is the end of measuring interval where change was detected. Duration is not reported as this report occurs for each measuring interval, thus if a network disturbance occurs over several measuring intervals, a slow voltage change will be generated for each measuring interval where the average value is below the limit. This Event is related to the EN 50160 "Voltage Changes" analysis.
Rapid Voltage Change	Refer to earlier description (Section 4.13).

Table 2. Summary of main under/over voltage events.

5. Flagging

The flagging concept avoids counting a single event more than once, in different event categories, e.g. counting a single dip as both a dip and a frequency variation.

Flagging is only triggered by

- Dips
- Swells
- Interruptions.

Flagging affects statistical measurements of:

- Frequency
- Voltage magnitude
- Flicker
- Unbalance
- Harmonics,
- Mains signalling

6. When are the values effective?

The PQ-Events are calculated by the PQ-Box 100 during the data recording, and the count of events is kept updated in the LCD display. Therefore, once the data is downloaded from the PQ-Box the PQ-Event setting/threshold values cannot be corrected/altered to re-evaluate the recorded data.

The EN 50160 analysis however, is performed by the WinPQ mobil software, and therefore it is possible to make some changes to settings, to re-evaluate the data.

Care/consideration is needed, as the EN 50160 analysis criteria that is being applied use the values in the then current session - not the settings that were loaded to the PQ-Box 100 to make the recording.

For example, if a recording was made using a PC with the narrow limit for voltage set to 98 % (rather than 95 %), and the data is then loaded to a PC where the “Setup”, “Common” setting is the normal 95 %, the EN analysis on the second PC will use the 95 % criteria.

7. The EN 50160 Standard

European Standard EN 50160:2007 “Voltage characteristics of electricity supplied by public distribution networks” defines, describes and specifies the main characteristics of the voltage at a network user's supply terminals in public low voltage (> 1 kV) and medium voltage (1 - 35 kV) electricity distribution networks under normal operating conditions.

The standard describes the limits or values within which the voltage characteristics can be expected to remain over the whole of the public distribution network and does not describe the average situation usually experienced by an individual network user. The object of this European Standard is to define and describe the characteristics of the supply voltage concerning:

- frequency
- magnitude
- wave form
- symmetry of the line voltages

EN 50160 term	Description
Rapid voltage change:	Change within limits of 100 % to 90 % of declared nominal voltage. Consider to be acceptable
Supply voltage dip:	Reduction of voltage between 90 % and 1 % of declared nominal voltage, for duration between 10 ms and 1 minute
Supply interruption:	Reduction of voltage to below 1 % of declared nominal voltage. Can be classified as prearrange or accidental. Accidental may be “short” (less than 3 minutes) or “long” (greater than 3 minutes)
Transient voltage	Short duration overvoltage’s (typically microseconds to few milliseconds)
Flicker:	Voltage fluctuations that can cause annoying changes in luminance of lamps: Short term severity (Pst) – measured over 10 minutes Long term severity (Plt) – measured over 2 hours
Voltage unbalance:	Unbalance of line voltages and/or phase angles
Mains signalling voltage:	e.g. ripple control (110 – 3 kHz) and power-line-carrier signals (3 -148 kHz)

Table 3. Main terms used by EN 50160.

Low voltage (< 1 kV) supply characteristics

	Measuring interval	Limits and monitoring period
Frequency	10 s	50 Hz +/- 1 % for 99.5 % of a year 50 Hz + 4 %, - 6 % for 100 % of the time
Voltage	10 minute averaging	+/- 10 % for 95 % of a week + 10 %, - 15 % for 100 % of a week
Supply voltage dips	10 minute averaging	Up to 1000 per annum permitted
Short interruptions	10 minute averaging	Up to several hundred per annum permitted, with approx. 70 % being less than 1 second
Long interruptions	10 minute averaging	Up to 50 per annum permitted
Transient voltages		Up to 6 kV permitted
Supply unbalance	10 minute averaging	negative phase sequence to be between 0 % to 2 % of positive sequence for 95 % of a week
Flicker	2 hours	Plt (long term flicker) <= 1 for 95 % of a week
Harmonic voltage		THD (up to 40th harmonic) <= 8 % for 95 % of a week
Harmonic voltage		2 <= 2 % 3 <= 5 % 4 <= 1 % 5 <= 6 % 6 to 24 even harmonics – 0.5 % 7 <= 5 % 9 <= 1.5 % 11 <= 3.5 % 13 <= 3.0 % 15 <= 0.5 % 17 <= 2 % 19 <= 1.5 % 23 <= 1.5 % 25 <= 1.5 %

Table 4. EN 50160 limits for low voltage networks (< 1 kV).